STUDYING CHALLENGES IN INTEGRATING TECHNOLOGY IN SECONDARY MATHEMATICS WITH TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE (TPACK)

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ABSTRACT

This paper describes challenges encountered by two secondary mathematics teachers when they try to integrate ICT devices in their classes. These findings are based on using the Technological Pedagogical and Content Knowledge (TPACK) context, the four dimension framework developed by Niess: 1) overarching conceptions of integrating ICT, 2) knowledge of instructional strategies and representations for teaching, 3) knowledge of students' knowledge of technology; and 4) knowledge of curriculum and curriculum materials that integrate technology with learning. By using this analysis, we explore the challenges that teachers face and suggest ways of improving strategies of integrating ICT instruction.

KEYWORDS

Computer Technology in Classrooms; The Technological Pedagogical And Content Knowledge (TPACK), Mathematics And Technology, Teacher Education, Mathematics Secondary.

1. INTRODUCTION

ICT devices have been praised for offering support for performing differentiated instruction, opportunities for collaboration, and ways to engage multiple intelligences for teaching and learning (Kelly & Tangney, 2006; Stoilescu, 2005). More specifically, in the case of mathematics ewducation, integrating ICT in mathematics education was often emphasized as providing a major support for teachers and students. Overall, ICT might have positive benefits for classrooms, if educators do not view the use of technology as a panacea and if they are knowledgeably and flexibly adapting ICT to the specific school settings (Kimmel & Deek, 1995; Ringstaff & Kelley, 2002).

Although researchers pointed out that computers might be used in education to improve learning outcomes (Roschelle, Pea, Hoadley, Gordin & Means, 2000), this is not easy to accomplish in practice. One of the reasons is that keeping up with the latest technological trends is very difficult for educators. For instance, educators such as Anderson (1992), Kaput (1992) and McRory (2006) have cautioned about the risk of ICT devices becoming obsolete in short time. In addition, because of the high cost of periodically purchasing software, there is a growing pressure for educators to produce better student learning outcomes.

In studying preservice teachers in mathematics, Niess (2005) recommends that the

TPACK framework should take into account four important aspects:

1. 1. An overarching conception of what it means to teach a particular subject, integrating technology in the learning process;
2. Knowledge of instructional strategies and representations for teaching particular topics with technology;
3. Knowledge of students' understandings, thinking, and learning with technology; and
4. Knowledge of curriculum and curriculum materials that integrate technology with learning.

This article is based on Niess design framework and explores difficulties encountered by teachers when they attempt to use ICT in secondary school mathematics classrooms. As well, the research describe the challenges mathematics teachers have in their efforts to integrate technology in teaching mathematics.

The goals of this research are: to understand existent pedagogical development ideas and pedagogical models of knowledge in the context of integration of technology into mathematics education by experienced teachers; and to document and analyze secondary school mathematics teachers' choices in integrating technology. The main research questions explored here was: What difficulties do teachers have when they try to integrate technology into mathematics classrooms.

2. BODY OF PAPER

2.1 Literature Review

Plair (2008) noticed that teachers that have been long time in the field and were not trained to integrate technology, did not use ICT devices in their classroom. As well, Li (2007), noticed that ICT integration in classrooms would not be positively received by many teachers as they view ICT as chore activity that is not directed with their core teaching goals.

Sugar, Crawley and Fine (2004) recognized that teachers need to have personal reasons of integrating technology. Consequently, when they were satisfied with their results, they did not have any incentives to integrate ICT in their classrooms.

In particular for the mathematics classroom, Healy and Hoyles (2001) noticed that technology posed particular challenges as using ICT was not a guarantee of successful instruction.

2.2 Methodology

This research is a qualitative study based on case studies (Creswell, 1998). I selected a large secondary urban school from Toronto. The school has a large majority of new immigrant students most of them coming from East Asia and East Asia. Data was collected from interviews, class observations and document analysis. Three experiences mathematics teachers with over 15- year experience participated in this study. Due to space limits, in this paper I will present only two teachers. The author discussed with the mathematics teachers different modalities entailed by the integration of computer technology in mathematics curriculum. Teachers' practices varied according to settings. Therefore, he spent a considerable amount of time reading different curricular and educational research literature for the purpose of understanding various solutions designed for these classrooms. Also, I was required to reflect on teaching acts and be able to critically evaluate interactions between teacher, students and group activities in order to understand the role of ICT in the mathematics instruction. In these stages, building, openness and the sense of sharing were essential. The challenges that appeared were classified in the four main categories developed by Niess (2005): a) overall conceptions; b) teacher instructional difficulties; c) student difficulties; and d) technological and curricular issues.

2.3 Findings

2.3.1 Overall Conceptions

Lawrence noticed that some mathematics teachers might be fearful of technology. Especially when the technical support is limited, the teachers should be able to work with technology on their own. Therefore, in order to overcome these difficulties, rigorous preparation is required for any teacher willing to implement computer technologies in classrooms. He said that teachers helped each other:

> If people are comfortable with it, they might use it... Secure enough to go to the classroom! Otherwise, they might look stupid and they might not know how to use it... We help each other; we try to help other people but teachers are on their own. They have to learn by themselves, practice by themselves, and learn how to do by themselves. This takes time and effort. You have to learn the technology, how to set it up and how to work it out.

Mark gave the example of Lawrence who, being supported to integrate technology in his classroom, was able to adjust it for his classes, although Lawrence's desire to master every minute detail might delay his plans of integrating new technologies into classrooms:

> When I tried to convince him to use computer technology in classroom, he was saying 'No, I have to learn it first.' But he did make an effort, a few years ago, when I asked him to use Fathom in data management classes. He made the effort but he did it in his way. He learned it first and then he studied it in class. But he realized that I was right in the first place. That he really did not know it as an expert... He needs to know something, a little bit; how to turn it on and how to run the program. That's about it. Now he is doing it. He does not need to be an expert in that specific technology. Nobody needs to be an expert but everyone has to take the risk.

2.3.2 Teacher Instructional Difficulties

While I observed Mark teaching, I noticed that the abstract part of mathematics does benefit from technology. For instance, he used a lot of technology when he taught geometry in the course Calculus and Vectors. He taught using Fathom and the Geometer's Sketchpad software. He was committed to integrating technology and to keeping the most difficult parts of mathematics in the course: abstract math, math as an art, and living as a mathematician. I asked for details about specific ways of teaching, what his goals are, and how he is trying to get these objectives accepted:

> I would like to have the whole picture. I want to know what the school is… Where the main efforts are going. … What the ministry is trying to do. I am trying to be aware of these changes in the curriculum, and changes to approaches of delivering the curriculum. Sometimes, it is a struggle to discuss with parents because some [parents] have not been to school for years. There are also other challenges. To give you particular examples, about ten years ago, the ministry introduced the new assistant evaluation approaches. It was written into the curriculum how we are supposed to evaluate the students. Not just what the students are supposed to know at the end of each course, but how it is supposed to be delivered and how it is suppose to be evaluated. As I said, this was ten years ago and the debate is still on. There are schools where still this has not been accepted.

For Mark, the technology is not helpful when someone is trying to substitute the "beauty of thinking" on mathematics with computer technology. However, the technology might help in understanding even the most abstract aspects of mathematical thinking:

> What the technology does not discuss is the art part of the mathematics where there is beauty of just thinking about the mathematics problem and sometimes we do not want the technology to spoil the thinking, and it is possible… all I am saying is that sometimes, there are areas of math where the technology cannot go, or it is not there yet. But the question is: do we need it there? I personally would not do it.

Lawrence and Mark acknowledged that cutting Grade 13 from the Ontario curriculum left students unprepared for university, in particular for mathematics. Mark described his concern:

> The curriculum changes, so it may not be simple to compare the level of achievement but, when I started working in 1997, we still had that five-year program. The students were more mature. Then we had to change the programs. There are now visible changes in our school.

2.3.3 Student Difficulties

When Lawrence was asked about Grade 9 students, he mentioned that "they seem to understand concepts but they cannot do anything with them". He was aware of the process of selecting students in applied mathematics courses and believed that the current strategies of integrating technology are getting more effective for them:

> Nine applied are never strong. But I think that [by integrating technology], they get to learn more. I cannot prove that. But I think that their EQAO scores are a little better, which means that the program is actually working. The classes are going now a little smoother and the students are less nasty, mean, or belligerent. They are more focused if they are going better.

When I asked Lawrence about his Grade 12 students who registered for the Advanced Functions course, he stated that being at this stage means that they will pursue higher education degrees. They were described as gifted and able to accomplish complex mathematical problems:

> This is a different matter. I treat them like university students. I try to give them interesting problems. I try to challenge them. I try to give them problems that are not obvious. Something that requires a bit of thought so they can play around with it. So I like to make them puzzles. … The textbook is pretty straightforward. I try to make them more open-ended.

2.3.4 Technical and Curricular Issues

Although integrating computer technology gave teachers some major advantages in mathematics instruction, these attempts were not without challenges. Teachers had some problems with technology and with instructing students with computers. In the first section, we will present each of these cases separately. In the second section, we will discuss the four-layer framework analysis with samples from all teachers together. When I asked him about different technologies that he might consider in teaching for the next semester, Lawrence mentioned Gizmos as an important tool for assessment and instruction fit for use in his classrooms. Not much in this moment. The only thing I see is using Gizmos, so they can set up to learn by using computer tutorials. Graphically, they visualize, they do problems. And there are a lot of problems, a lot of Gizmos. I used a few, but I think that this is going to be a thing in the future. Using these little programs called Gizmos. But that requires that the kids have individual computers. I can bring one computer only in a regular classroom, so I have to bring them to the lab. And to have everybody work on that it is a bit of a problem. There are not many labs. It's only one lab. You got to share.

3. CONCLUSION

3.1 Summary of Difficulties by Using the TPACK Four-Layer

3.1.1 Overall Conceptions

The teachers experienced some dissonance between their theoretical and practical conceptions. For instance, as they were recently trained in Web2.0, we expected to see them working on implementing Web 2.0 technologies in their classrooms. It appeared that these technologies required a new teaching paradigm that the teachers did not know how to implement easily. These teachers clearly wanted to use technology in their classrooms. For example, they thought that working with graphic calculators was important, although there was no general consensus on how it could be used. The issue of appropriate use of calculators was divided between keeping them as they are, bringing in a new generation of graphic calculators, or replacing them with personal computers.

3.1.2 Teacher Instructional Difficulties

In the TPACK framework, these challenges are located at the intersection between pedagogy, content, and context. Some of the teachers' challenges were caused by the change of software and hardware. When the software or hardware used by teachers change, then teachers need time to update their skills (Galbraith et al., 2001). For instance, the present version of Geometric Sketchpad is very different from the older versions on which these teachers were trained. The new version is more complex and has some different features. Because the geometry curriculum has been reduced drastically, the importance of Geometer's Sketchpad has decreased. Another discrepancy was noticed in the Advanced Functions course, where many problems from the current textbook were solved with Geometric Sketchpad, but Mark chose to solve these problems using Fathom software, which was not mentioned at all in the textbook. An adequate textbook for this course would make the Geometric Sketchpad software less necessary and would require the inclusion of the Fathom
Some curriculum areas were not covered with current software products. These made teachers feel uneasy. For instance, in the Calculus and Vectors course, there was no software to cover the second half of the course. Therefore, Mark had to use several software products for different lessons. This approach could not be followed by many teachers as becoming familiar with the content of this course was not covered by any workshop or seminar and was an individual effort.

3.1.3 Student Difficulties

Students had specific challenges in the process of integrating technology. Studies from Niess (2005) and Mishra and Koehler (2008) acknowledged a specific role for students. Although students were familiar, in general, with computer technology, the adaptation to specific mathematic tools should not be taken for granted (Drier, 2001; Ronau et al., 2008). For instance, in the Data Management Grade 12 course, the use of Excel, PowerPoint, and Word presented some challenges when students started to use them for the project. Sometimes, they had difficulties inserting mathematical formulae; sometimes they had difficulty integrating data in their project with previous texts, presentations, and game scenarios.

The Grade 9 Applied students had numerous challenges. On some occasions, the students from the Grade 9 Applied course were not able to use graphic calculators for assignments. Instead, they tried to avoid the use of graphic calculators and solve the problems on paper only. When they were brought into the computer lab, they attempted to use technology for things unrelated to learning mathematics. For instance, some of them preferred to look for games, videos, or music and the teacher had a hard time trying to convince them to keep their focus on working on the mathematical software. Some students were using the graphic calculators and computers carelessly. This triggered the teachers to ask them to be more responsible when they use technology. These experiences are different for different courses, students and teachers, and they represent important aspects that need to be considered when teachers attempt to integrate technology in the classroom.

3.1.4 Technical and Curricular Issues

In the TPACK framework, these challenges intersect between technology and context. Some limitations were due to challenges posed by the technology, either hardware or software problems. For instance, although the prices have dropped significantly for equipment and software, purchasing technology still remains challenging for public schools. In addition, the technology becomes outdated quickly (McCrory, 2006) so other financial efforts are required to purchase new equipment. Teachers commented that financial aspects were seriously considered in purchasing computer technology as the price for some products were prohibitive. In addition, there were some issues with the manipulation of the technological devices. For instance, some students dropped the graphic calculators on the floor and this might reduce their functionality over time. Some graphic calculators ran out of batteries and some had deteriorated. The teachers used different versions of the software from that used in the examples in the textbooks. However, these were reasonable challenges and the teachers were able to fix or work with them.

A considerable problem was the lack of computer technology. If all of the teachers were determined to integrate technology in their classrooms, the school could not afford to have all of these technologies and use them simultaneously. Therefore, as noted in Maor's study (2003), the IT infrastructure represented a serious problem that teachers had to consider. The software generated an important number of challenges. The software was not always able to help students. Mark stated that some units did not offer many possibilities for using computer technology with the students. Each course had some areas where no actual computer technology could have any impact on student learning.

3.1.5 Summary of Challenges

The process of integrating technology in mathematics classrooms posed various types of challenges that were found on all four layers of analysis. Sometimes there were problems with the technology, sometimes the curriculum did not afford much support for learning by using software, and sometimes students or teachers themselves were challenged. Still, the teachers felt that the technology offers opportunities for supporting students' learning and technology is helpful for teaching and assessments. The two teachers displayed a strong understanding of challenges that might appear in the use of technology in mathematics instruction. In addition, their experience in using technology, in teaching mathematics, and in integrating technology in mathematics gave them confidence and supported their pedagogical efforts to integrate computer technologies in mathematics classrooms. This evidence was demonstrated in multiple forms: teaching activities, class assignments, interactions between teachers and students, and interviews and discussions about using technology in mathematics. The teachers mentioned that, despite these challenges, the role of technology was still engaging for their students and that computer technology is requested in their classrooms.

Similar to Harris's (2008) description of experienced teachers linking the integration of technology with spontaneity, Lawrence mentioned:

I always read my students. When I teach a class, if I know that they do not know anything about what I am talking about, I stop teaching that... Because you got to be flexible, you got to be adaptable. You got to read the situation, you got to read the people.

3.1.6 Discussions

Why are so few teachers currently integrating technology in secondary school classrooms (Cuban, 2001), particularly in mathematics classrooms? This study did not explore the root causes that make technology difficult to be integrated in mathematics curriculum. Rather, this research was focused on successful practices of integrating technology in mathematics, revealing both individual and institutional efforts that made these attempts possible.

Perhaps it might be argued that some software products such as Excel and PowerPoint are easy to use because teachers have been using them in other contexts before. Other software products such as SMART Boards or TI-Nspire Graphic Calculators might be new and require some training. For some specific software products for mathematics curriculum, such as Fathom or the Geometer's Sketchpad, an extensive period of training is required. These are cases when software requires an extensive period of learning, training, and assistance in teaching them in the classroom and therefore teachers should consider them attentively.

PD programs for mathematics teachers should provide more opportunities to help the teachers integrate technology in the classroom. Mark mentioned that the workshops and seminars only trigger an interest in a specific problem. Indeed this is the case for an experienced math teacher who has already taught using computer technologies in the classroom. But the problem is different for a teacher who has not yet tried to use computer technology in their teaching.

Technical support is very important. For teachers who have strong expertise in computers, it was fine to have technologists from outside the school to support them. However, for teachers who were new to technology, this could be frightening. Therefore, for new teachers, maybe the technological support should be embedded in the school in order to encourage them to efficiently use technology in classrooms.

Therefore, it is very important to establish mentorship relationships with teachers who are already comfortable with computers in teaching mathematics. It is essential to establish collaboration between technical support staff and teachers in order to solve various technological issues. The administration of the school should support efforts to integrate computer technologies in mathematics classrooms. Likewise, time should be allowed for designing and integrating technology in classrooms (McDougall, 1997). In addition, a more specific agenda for sharing ideas, skills, and computational resources should be considered.

As the teachers mentioned, they are left alone most of the time to teach. This might explain why other teachers did not succeed in implementing technology in the classroom. Therefore, in order to be able to integrate new technologies and use them efficiently in front of the class, teachers need to be helped to develop planning, collaboration, and determination. They should be able to reflect on strategies, representations, and visions that make purposeful use of a specific technology for their students.

A major problem is that, although the integration of technology in education has been recommended for almost three decades, in fact this process of integration is still not implemented on a large scale. The process of integrating technology has not penetrated every school as expected. This is due to different reasons. At the beginning, the main reason was the high costs required. Now, it seems to be that the main reason is that the integration of technology is still an option and therefore teachers can delay whenever they wish. Unfortunately, as Mark, this process of integrating technology in curriculum still remains at the stage of recommendation. This lack of specific deadlines might trigger a lack of planning and clarification for the specific use of computer technology. This might be because of lack of clear guidelines for integrating technology in mathematics classroom from teachers, administrators, or the school board.

Teaching is an iterative process (Koehler & Mishra, 2008) and, as the models of Rogers (1996) describe, the technology takes different stages of integration. Therefore, I see the process of integrating technology as an important and sustained leadership effort that needs to be carefully planned. More precisely, teachers and administrators should consider a long term perspective in plans to implement technologies into classroom.

The technology is changing fast and therefore it will always remain a challenge implementing in purposeful way in mathematics education. As Grandgenett (2008) recommends, in order to provide adequate training for inservice and preservice teachers, the goals of the instruction should flexibly target teachers to help foster their skills and attitudes in using technology in thoughtful ways.

As Mishra and Koehler (2007) note, "teachers construct curricula through an organic process of iterative design and refinement, negotiating among existing constraints, to create contingent conditions for learning"

(p. 2222). This was also noticed in this study as using technology produced major changes in teaching. For instance, the mode of teaching and the assignment procedures were totally changed from a traditional classroom where the teacher talks and writes on the blackboard. In addition, the technology changed the way students interacted. As a result, the roles of collaborative and cooperative strategies were redesigned.

The technology changed the control and the management of classrooms. For instance, by making digital resources available to students, the students had access to them to learn without any effort from teachers. In their turn, the teachers interacted with students only at critical points when they needed specific advice or coordination. These strategies are developing over time. As Koehler and Mishra (2008) suggest, the preparation of teachers should be a spiral process, starting first with technologies that are simple and familiar to them. They might extend afterward with products of increasing difficulty. Therefore, aspects of and strategies for time management, interaction, and collaboration should be carefully considered in integrating technology.

The major contribution in this study was to explore effective integration of computer technology in mathematics education. This study shows two different ways of integrating technology in classroom. The teacher participants in this research have different personal, pedagogical and technical backgrounds. In order to teach their students mathematics, they used different technologies or use the same computer device differently. Yet, they were able to show, in different ways, that their pedagogical approaches of integrating technology in mathematics classrooms remain successful.

This study makes three main contributions to the research in mathematics teaching:

1. To help teachers develop pedagogical skills and also a conceptual understanding in integrating technology in mathematic classrooms,
2. To learn more about TPACK and how it is designed as a theoretical and practical approach in assisting secondary school mathematics teachers better understand how to use technology tools in teaching mathematical concepts, and
3. To identify secondary school mathematics teachers' challenges with using educational technologies in classrooms, as they investigate pedagogical and technical issues and modalities designed to improve mathematical teaching and learning skills.

It is important to have teachers be skillful in mastering computer techniques and be able to show these to students. In this research, I found that it is important to have in a mathematics department a critical number of teachers who are interested in integrating technology in the classroom. Without fostering an adequate support group, teachers have various individual interests and would not be able to implement technology in classrooms. Teaching with technology requires interactions with colleagues and teamwork.As Gopalakrishnan (2006) states, "Individuals from both educational and technical orientations can support teachers with technology integration as long as they are able to 'translate' between the two domains and work with users of varying technical abilities" (p. 54). Therefore, it is very important to establish mentorship relationships with teachers who are already comfortable with computers in teaching mathematics. It is essential to establish collaboration between technical support staff and teachers in order to solve various technological issues. The administration of the school should support efforts to integrate computer technologies in mathematics classrooms. Likewise, time should be allowed for designing and integrating technology in classrooms (McDougall, 1997). In addition, a more specific agenda for sharing ideas, skills, and computational resources should be considered. As the teachers mentioned, they are left alone most of the time to teach. This might explain why other teachers did not succeed in implementing technology in the classroom. Therefore, in order to be able to integrate new technologies and use them efficiently in front of the class, teachers need to be helped to develop planning, collaboration, and determination. They should be able to reflect on strategies, representations, and visions that make purposeful use of a specific technology for their students.

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takes different stages of integration. Therefore, I see the process of integrating technology as an important and sustained leadership effort that needs to be carefully planned. More precisely, teachers and administrators should consider a long term perspective in plans to implement technologies into classroom. The technology is changing fast and therefore it will always remain a challenge implementing in purposeful way in mathematics education. As Grandgenett (2008) recommends, in order to provide adequate training for inservice and preservice teachers, the goals of the instruction should flexibly target teachers to help foster their skills and attitudes in using technology in thoughtful ways. As Mishra and Koehler (2007) note, "teachers construct curricula through an organic process of iterative design and refinement, negotiating among existing constraints, to create contingent conditions for learning" (p. 2222). This was also noticed in this study as using technology produced major changes in teaching. For instance, the mode of teaching and the assignment procedures were totally changed from a traditional classroom where the teacher talks and writes on the blackboard. In addition, the technology changed the way students interacted. As a result, the roles of collaborative and cooperative strategies were redesigned. The technology changed the control and the management of classrooms. For instance, by making digital resources available to students, the students had access to them to learn without any effort from teachers. In their turn, the teachers interacted with students only at critical points when they needed specific advice or coordination. These strategies are developing over time.

As Koehler and Mishra (2008) suggest, the preparation of teachers should be a spiral process, starting first with technologies that are simple and familiar to them. They might extend afterward with products of increasing difficulty. Therefore, aspects of and strategies for time management, interaction, and collaboration should be carefully considered in integrating technology. The major contribution in this study was to explore effective integration of computer technology in mathematics education. This study shows two different ways of integrating technology in classroom. The teacher participants in this research have different personal, pedagogical and technical backgrounds. In order to teach their students mathematics, they used different technologies or use the same computer device differently. Yet, they were able to show, in different ways, that their pedagogical approaches of integrating technology in mathematics classrooms remain successful. This study makes three main contributions to the research in mathematics teaching: 1.To help teachers develop pedagogical skills and also a conceptual understanding in integrating technology in mathematic classrooms, 2. To learn more about TPACK and how it is designed as a theoretical and practical approach in assisting secondary school mathematics teachers better understand how to use technology tools in teaching mathematical concepts, and 3. To identify secondary school mathematics teachers' challenges with using educational technologies in classrooms, as they investigate pedagogical and technical issues and modalities designed to improve mathematical teaching and learning skills.

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